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Title: Report to NCSP on FY21 DANCE and NEUANCE measurements of 233U(n,)

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Report to NCSP on FY21 DANCE and NEUANCE measurements of ^{233}U(n,γ)

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1 New measurement at LANL using DANCE and NEUANCE

The experiment was performed by the end of the CY20 runcycle at LANSCE. Due to transportation issues the material arrived at LANL on 1st December. Two ^{233}U samples, of 20 mg and 10 mg were produced at LANL by stippling, which has proved a robust, cost-effective method for producing actinide samples in the range of 1-20 mg in a small (<1 cm) diameter with very high efficiency. The 20 mg sample (figure 1 left) was placed inside NEUANCE (figure 1 right) on FP14 on 11th December, was measured over 10 days, and the 10 mg sample was placed in the beam for 1 day. The rest of the beam time was used to measure radioactive γ sources for calibration, background measurements and tests to define the ^{233}U windows required during the data taking, also some measurements were done with a ^{235}U sample to cross-check the performance and the systematics.

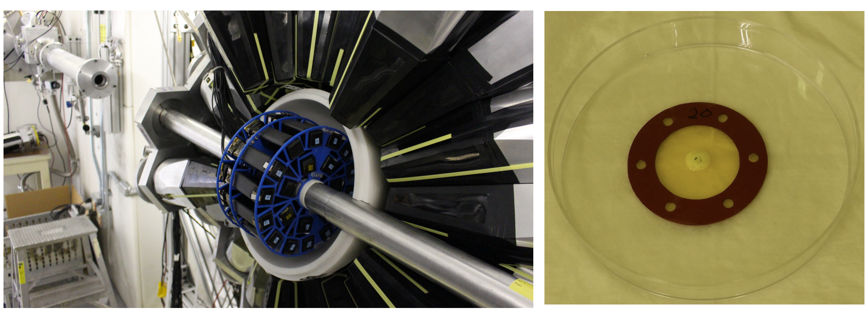

Figure 1: The NEUANCE instrument placed inside DANCE (left), and the 20 mg ^{233}U sample.

2 Data Analysis

The first step on the data analysis consisted in calibrating the DANCE and the NEUANCE crystals. The intrinsic radioactivity of the BaF_2 crystals was used to calibrate the DANCE crystals by using the α-decay chain of the ^{226}Ra present inside the BaF_2. The NEUANCE crystals were calibrated using ^{22}Na, ^{88}Y and ^{137}Cs γ sources.

Once that the calibrations have been finished, the next step on the data analysis consists in defining Pulse Shape Discrimination (PSD) windows to separate the neutrons and γ's from NEUANCE. These windows will be used to identify fission events with NEUANCE by finding coincidences between the signals from the neutrons and the γ's produced in fission reactions. Then a second coincidence method will be applied between DANCE and NEUANCE to identify the γ's that come from the Fission Fragments, and the signals that fulfill this coincidence condition will be tagged, to be later substracted in the capture cross section calculation. The coincidence method was successfully used in a very similar analysis to measure the ^{235}U and ^{239}Pu capture cross section using a PPAC combined with DANCE respectively in [1, 2].

2.1 Pulse Shape Discrimination

The good separation between neutrons and γ's achieved with NEUANCE using the 20 mg ^{233}U sample is shown in figure 3, which represents the difference between the Long and Short components of the signal divided by the Long component as a function of this last one. Two windows have been defined to separate the fission neutrons from the γ's, whose events are distributed in two lines on the figure, the events on the top line correspond to neutrons and the events on the bottom line to γ's.

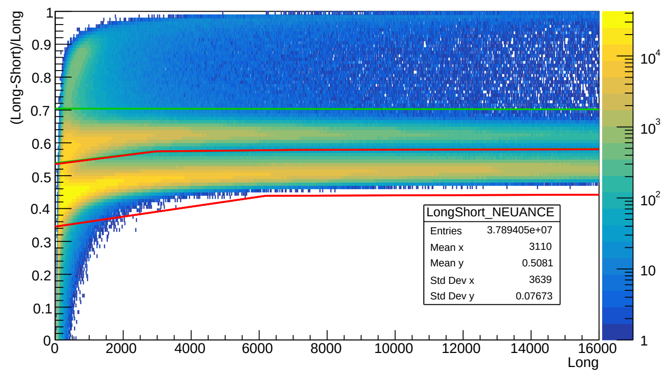

Figure 2: PSD plot showing the windows used to separate fission neutrons (green window) and γ's (red window) measured with NEUANCE.

2.2 Neutron Energy calculation

The neutron energy is calculated from the Time-of-Flight of the neutrons, the time that they take to travel from the spallation source to the ^{233}U target, using the relativistic formula, equation 1, that can be simplified to the non-relativistic one, equation 2, for neutron energies below 1 MeV. The detectors and sample are located at the 20 m flightpath (FP-14).

$$E_n = mc^2(\gamma - 1), \quad with \quad \gamma = \frac{1}{\sqrt{1-(v/c)^2}} \tag{1}$$

where m is the mass of the neutron at rest, c is the velocity of light in vacuum and γ is the Lorentz factor.

$$E_n = \frac{1}{2}mv^2 \tag{2}$$

The preliminary raw counts obtained with DANCE before the fission γ's subtraction corresponding to capture and fission γ's is shown in figure 2 (left), and the one obtained with NEUANCE before applying the coincidence method is shown in figure 3 (right), both of them for a reduced amount of the total statistics.

3 Conclusions and next steps

Preliminary raw counts spectra have been obtained for both DANCE and NEUANCE in the first steps of the data analysis. The next step on the analysis consists in searching for coincidences between neutrons and γ's with NEUANCE to identify the fission events, and then a second coincidence method between DANCE and NEUANCE will be used to tag the fission γ's and suppress them in the calculation of the capture cross section.

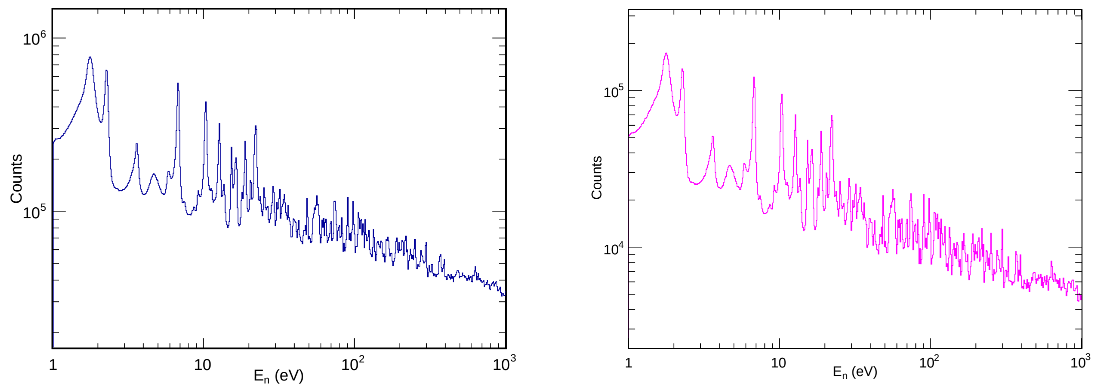

Figure 3: Preliminary raw ^{233}U counts in the Resolved Resonance Region (RRR) obtained from DANCE before the fission γ's subtraction (figure on the left), and from NEUANCE before coincidences (figure on the right). Since these spectra are taken from raw events before fission suppression, it is unsurprising that the DANCE spectrum is dominated by fission events.

A second measurement of the ^{233}U capture cross section, using the thick target ($\sim$20 mg) has been planned for June-July 2021, to complete the statistics needed above 10 keV.

Part of this work was presented in the NCSP-TPR meeting (February 2021), and in the NCSP Spring Newsletter (March 2021).

References

[1] M. Jandel et al., Phys. Rev. Lett. **109**, 202506 (2012).

[2] S. Mosby et al., Phys. Rev. C **97**, 041601 (R) (2018).